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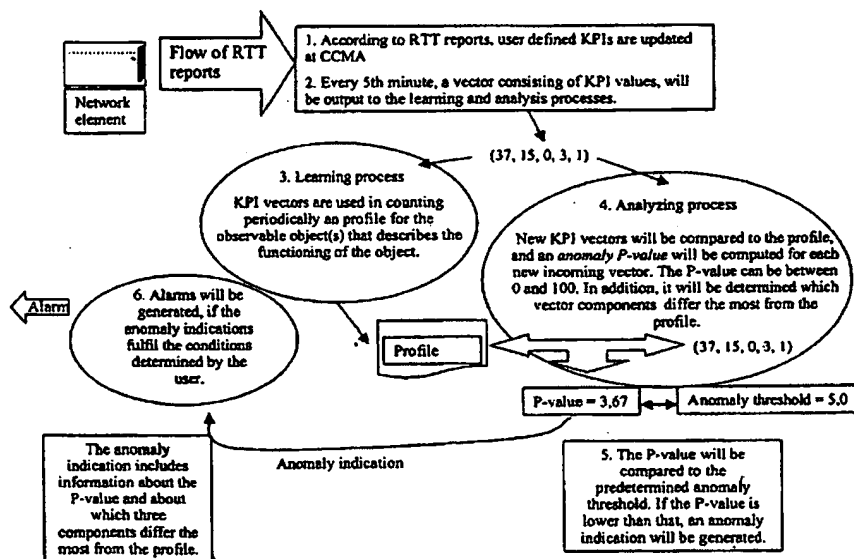
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(54) Title: SYSTEM, DEVICE AND METHOD FOR AUTOMATIC ANOMALY DETECTION



(57) Abstract: The invention relates to a method and system for monitoring the behaviour of at least one observable object, e.g. a network element, of a network, wherein at least one parameter of the observable object is repeatedly detected. An actually detected parameter is input to a learning process and to an analyzing process, wherein the learning process forms a reference, based on at least two detected parameter values, for describing the behaviour of the observable object. The analyzing process compares the input parameter and the reference for detecting an anomalous behaviour. The parameter preferably is a vector which comprises several values describing properties or functioning of the observable object, and is formed based on events and/or reports from the object.

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TITLE

5 SYSTEM, DEVICE AND METHOD FOR AUTOMATIC ANOMALY DETECTION

DESCRIPTION

10 FIELD AND BACKGROUND OF THE INVENTION

The invention relates to a system, device and method for automatic anomaly detection, in particular to the automatic detection of quality indicators updated in real-time.

15

Some networks may provide a network infrastructure for operators for offering services to the subscribers. Because network infrastructure is very complex and may be affected by the environment, problems may arise which decrease the quality of service experienced by the subscribers. If such problems are detected and solved quickly and efficiently, the quality of service may be kept at a very high level.

20

The expectations of customers regarding access to services over the Internet are becoming more demanding, and response times for access to critical data are getting more important. As a result, efficient real-time support over networks will be critical for the continued growth of the Internet and intranets. This support for real-time services requires "Quality of Service" management procedures in mobile networks so that the scarce spectrum can be used as efficiently as possible.

30

The significant growth of networks including an increased

number of different elements requires sophisticated methods and tools that enable centralized network and service monitoring in large networks so as to provide effective network operation.

5

Mechanisms for detecting abnormal situations belong to one of two major categories, namely rule-based detection mechanisms and anomaly detection mechanisms (sometimes called also novelty detection mechanisms). Rule-based detection mechanisms attempt to recognize certain behaviour patterns which are known to be improper like exceedings of given thresholds. Thus, rule-based detection mechanisms have two severe limitations: they can only detect problems which have occurred before and which have been explicitly taught to the detection system or programmed into it. Anomaly detection systems (ADS), as used in this application, reverse the detection problem: they are taught what normal behaviour is, and anything deviating significantly (by a predetermined margin) from the norm is considered anomalous. ADS mechanisms are capable of detecting potentially problematic situations without explicit training of such situations. An example of an ADS is disclosed in the article: Höglund, Albert: *An Anomaly Detection System for Computer Networks*, Master of Science thesis, Helsinki University of Technology 1997. Thus an ADS is defined as a mechanism which is trained with normal behaviour of the target system. Accordingly, an ADS flags every significant deviation from normal as a potential anomaly. In contrast, a rule-based detection system is trained with known modes of abnormal behaviour and it can only detect the problems that have been taught to it.

Generally it is difficult to have alarms indicating quality of service problems. It is also very challenging to define proper thresholds which generate appropriate numbers of

- alarms. If the alarm thresholds are too high, there are no notifications about problems. If the alarm thresholds are too low, there are too many alarms to be handled efficiently. If the alarm thresholds are updated manually, the updating is very cumbersome and must be performed whenever the network conditions change. Further, alarm thresholds are normally different in different parts of the network which leads to additional problems.
- 10 Usually the operators are not able to freely define Key Performance Indicators (KPIs) which are monitored. The KPIs are defined by network manufacturer and the operator can only select whether or not to use a KPI. In systems which monitor predefined KPIs of a network element, the operator may be able to define alarm thresholds for the KPIs manually. In such cases, it is only possible to monitor the most important issues on a general level. Furthermore, the adjusting of alarm thresholds is very difficult.
- 20 With an ever-increasing alarm flow it is vital that the network operator has means to cut down the number of less important alarms and warnings. In this way the operating personnel can concentrate on service-critical alarms that need to be dealt with immediately.
- 25 When simply relying on the counting the number of error-indicating events, and issuing an alarm when the number of events exceeds some user determined value, there may be some situations where this solution does not function properly.
- 30 For example, in front of Helsinki there are some islands with a single base station on them. Boats with several hundreds of passengers will bypass the islands every now and then, and naturally the base station on those islands may be very highly loaded by the mobile subscribers on the boat. When the

breaking of calls is counted for causing alarms, such alarms will be false, because the calls are broken by natural phenomena, i.e. the bypassing ship that is moving out of the coverage area of the mobile network, and not by any network malfunction. However, in some other base station a similar course of events might indicate some severe network problem.

The article: Höglund, Albert: *An Anomaly Detection System for Computer Networks*, Master of Science thesis, Helsinki University of Technology 1997, discloses an ADS for a Unix-based computer system. The disclosure contents of this article are in toto incorporated herein by reference. The disclosed system consists of a data-gathering component, a user-behaviour visualization component, an automatic anomaly detection component and a user interface. The system reduces the amount of data necessary for anomaly detection by selecting a set of features which characterize user behaviour in the system. The automatic anomaly detection component approximates users' daily profiles with self-organizing maps (SOM), originally created by Teuvo Kohonen. A crucial parameter of a SOM is a Best Mapping Unit (BMU) distance. The BMUs of the SOMs are used to detect deviations from the daily profiles. A measure of such deviations is expressed as an anomaly P-value. According to reference 1, the ADS has been tested and found capable of detecting a wide range of anomalous behaviour.

US 5,365,514 discloses an event-driven interface for a system for monitoring and controlling a data communications network. The device is listening to serial data flow in a LAN (Local Area Network), and provides a control vector. The device is not structured to receive and analyse packets of a packet flow.

SUMMARY OF THE INVENTION

The invention provides a system and method for automatic
5 anomaly detection, in particular for the automatic detection
of anomalies in quality indicators updated in real-time.

The present invention provides a system, method and/or device
as defined in any of the independent claims or any of the
10 dependent claims.

According to one aspect of the invention, a method and system
are provided for monitoring the behaviour of at least one
observable object of a network, wherein

15 at least one parameter of the observable object is
repeatedly detected,

at least one parameter is checked with regard to
fulfilling predetermined criteria,

20 a vector is formed based on the monitored parameter
depending on the result of the checking step,

and the formed vector is evaluated for monitoring the
behaviour of the observable object.

The observable object can be any monitored entity in the
25 network, e.g. a network element, a subscriber, subscriber
group, geographical area, circuit group, service, or alike,
that can be identified and referred to in predetermined
criteria that are used in the forming of the vector. The
vector comprises several values which describe properties or
30 functioning of the observable object. The predetermined
criteria and the observation period, during which one vector
is formed, are user definable.

The formed vector is preferably input to a learning process

and to an analyzing process,

the learning process is forming a reference, based on the input vector and a previous value of the reference or at least one previous input vector, for describing the behaviour of the observable object, and

the analyzing process is comparing the input vector and the reference for detecting anomalous behaviour.

The vector is preferably formed based on detected values in RTT (Real Time Traffic) reports. An RTT report contains fields defining parameters of phenomena or events in the network e.g. for calls it can include the reason code for call break, a length of call, and/or a number of handovers during call to name a few.

The reference formed by the learning process may be a profile vector generated from at least two vectors. In another case, e.g. in a SOM (Self-Organizing Map) case, the profile is not a vector but is made up e.g. of the trained SOM itself and the Best Mapping Unit Distance Distribution (BMUDD).

Key Performance Indicators (KPIs) which are computed and monitored measure the quality of service seen by the subscribers. The number of parameters that fulfil the predetermined criteria during an observation period, can be used for forming these KPI values which form part of the vector, each parameter having its own criteria. E.g. when an RTT value fulfils the predetermined criteria, the value of one KPI is increased by one. The fulfilling of the predetermined criteria can be checked by comparing fields of an RTT report or values derived from them by given functions to predetermined field thresholds.

One condition can e.g. be

If (reason code = 4 (or 5 or 6)) and (length of call > 4 minutes) and (number of handovers = 0) the corresponding KPI value would indicate, how many breaking calls that fulfil that condition, happened during the observation period. These KPI values are then put together to form a vector for the learning and analyzing processes.

In accordance with one aspect of the invention, the invention provides a system for collecting data from an observable object, e.g. a network element, in real-time and for automatically detecting, from this data, anomalies in the quality of service in comparison to the normal behaviour of the observable object. Anomalies are detected based on user-definable key performance indicators (KPIs) of the observable object. KPIs measure the quality of service seen by the subscribers. Detected anomalies indicate potential problems in the quality of service.

The system can be connected to any network element which sends a report to the system in real-time about an event, such as a call attempt or a short message, which occurred in the observable object or due to some action of an observable object. Reports are defined in configuration files enabling the adaptation of the system to any observable object. Various data are included in the reports. The reports preferably contain fields about subscriber information, event details, used network resources, used additional services and quality indicators. These fields can be used to define KPIs by the user.

The system learns the normal values of the KPI vectors and is thus capable of detecting and indicating an abnormal behaviour of the observable object when the actual KPI vectors deviate significantly from the learned KPI vectors.

These indications can be interpreted as alarms about potential problems. In a preferred implementation, the system not only learns the normal values of the KPIs, but also, in what combinations they occur. A set of perfectly normal KPI values can then represent an anomaly, if the values occur in an unusual combination.

Advantages of the invention include the following: provision of a flexible solution for any observable object. Further, the solution is observable object independent. The KPIs can be defined by the users. User definable KPIs are easy to introduce and monitor. The KPIs are preferably updated in real-time. In practise, KPI updating intervals, i.e. monitoring intervals of more than e.g. 5 or 10 seconds, preferably at least 30 seconds or more are sufficient. The amount of work is reduced because there is no need to define and iterate alarm thresholds, and no need for maintenance after the KPIs are defined. The provided system and method automatically adapt to different situations as normal situations in case of slowly changing normal situations.

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The invention provides means and functions for monitoring applications. Real-time network surveillance and cost-efficient operations are possible at both the regional and global level. Alarm filtering applications help to reduce operator workload by adjusting the network information flow to an optimal level. The invention may provide alarm manuals and alarm history information to assist in troubleshooting network problems.

The invention allows efficient problem detection and working procedures. By means of centralised monitoring tasks, automation and integration of other management systems is possible. The workload and costs of managing the network are

reduced as a result of improved network quality through rapid problem detection and correction. Fewer site visits are necessary due to centralised operations.

- 5 The invention provides adjustable alarm sensitivity. Features of a preferred embodiment include: receiving traffic reports from observable objects, e.g. network elements; using reports in counting key performance indicators (KPI); forming vectors of KPIs; and using the vectors as input data to an algorithm
10 that learns the normal functioning of the observable objects and detects anomalies.

BRIEF DESCRIPTION OF THE DRAWINGS

15

Fig. 1 illustrates a basic structure of a communication system in accordance with an embodiment of the invention;

Fig. 2 shows the structure of another embodiment of the
20 invention;

Fig. 3 shows the steps of another embodiment of the invention;

25 Fig. 4 shows a self-organizing map;

Fig. 5 is a variation of Fig. 4, with circles centred around the neurons of the SOM;

30 Fig. 6 is a process chart illustrating a preferred embodiment; and

Figs. 7A to 7C illustrate different presentations of time.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE
INVENTION

5 Basically, the invention provides a configurable system and method for collecting data from various observable objects, e.g. network elements, part of them, users, user groups or services etc., and detecting anomalies in the QoS automatically, by comparing the data to data that has been
10 collected when the network is working normally. Anomalies are detected based on user definable "key performance indicators" (KPI) of the observable object. The system learns the normal values of the KPI vectors and is thus capable of indicating the abnormal behaviour of the network. The system alarms for
15 anomalies when the deviation is strong enough compared to normal behaviour. A benefit is that the user does not need to enter absolute threshold values.

According to a preferred embodiment, the invention provides,
20 or is used in, a system that monitors the functioning of a communication network, e.g. a mobile network, and detects anomalies. The idea is that the system learns the normal functioning of the network, and is thus able to detect what is not normal.

25 In one of the preferred implementations of the invention, the system or process may include the following steps:

- Receiving of RTT reports (RTT = Real Time Traffic report, preferably delivered as a UDP message) from at least
30 one network element. An RTT report indicates some events associated with the observable objects, and it consists of several fields, describing different attributes of the event (eg. event code, reason code, time information, subscriber identification). There can be an unlimited number of fields

in the RTT report, e.g. a report from a Mobile Switching Center (MSC) has about 100 fields;

- RTT reports will be used in counting KPI (Key Performance Indicator) values. The KPI value, or one of the KPI values, may be the number of RTT reports in a given time period, that fulfil some predetermined condition, e.g. conditions for field values.

In one KPI value, there may be several field value conditions with some logical function (ANDed or ORed).

10 e.g.

KPI(1) = number of (RTT(field1)=value1 and
value2<RTT(field2)<value3),

or,

KPI(2) = number of (RTT(field1)>value1).

15

- Forming of vectors, by using the KPI values as vector components. The vector describes the functioning of the observable object.

- Using the vectors as input data to an algorithm. In this invention, the algorithm preferably is a neuron (neural) network algorithm such as SOM (self organising map) or a clustering algorithm such as the K-means algorithm or some other corresponding neural or statistical algorithm.

- The algorithm will learn the normal functioning of the network, and the algorithm will form a profile describing the normal functioning of the network. In a preferred embodiment the profile consists of nodes or cluster centroids.

- Finding best mapping nodes or cluster centroids for incoming vectors;

- Counting distance between new incoming vectors and the best mapping node or cluster centroid.

- Counting a distribution for distances;

- Finding out whether there is a probability for an incoming distance less than predetermined value;

- Alarming, if answer is yes.

According to one aspect of one of the preferred embodiments of the invention, it includes the steps of forming vectors of counted KPI values, and inputting those vectors to a neural algorithm or the like.

An RTT-report ('Real Time Traffic' report) is a structured report of an event in the network. RTT reports are binary data records consisting of fixed-width fields in a predefined order. The structure of the report is definable e.g. by a user. The report contains fields like subscriber number, reporting time, time of A-call, time of B-answer, call ending type (DX Cause), etc. A network element (NE) sends an RTT-report to a system after a certain event. In a system, e.g. a Traffica system, KPIs are updated based on the values of different fields in the RTT report. Note that the system can combine data from different NEs which means that one can have network-wide or system-wide KPIs.

20

In GSM networks, an RTT report can be generated after each call, short message, handover, location update etc. RTT reports for calls contains fields such as:

-start time of the call,

25 -end time of the call,

-identification of A and B subscriber (MSISDN, IMSI),

-location information of A and B subscriber (cell, lac),

-used network resources (BSC, circuit group),

-used mobile equipment (IMEI),

30 -used services,

-clear code (DX cause) - the reason code for call ending,

-etc.

In the following, an example of an RTT report definition is

listed.

Name of a field, offset, data type+length

Sub_Id 0 UINT16

Report_Date 2 BCDDATE

5 Report_Time 6 BCDTIME

A_Caller_Id 10 UINT32

B_Caller_Id 14 UINT32

B_Answered_Date 18 BCDDATE

B_Answered_Time 22 BCDTIME

10 Dx_Cause 26 UINT16

and so on.

In GPRS networks, an RTT report can be generated after each attach/detach, PDP context activation/deactivation etc.

15 On the system side, e.g. Traffica side, the structure of RTT report is preferably defined in ASCII files, meaning that defining new RTT report types is very simple and flexible.

20 The RTT-reports can also be replaced by any (semi) structured messages, e.g. alarms, that are describing network operations or events and that can be handled by a feature extractor. Furthermore they can be sent not only after certain events, but also after certain fixed time period or after a fixed number of certain events.

25

KPI (Key Performance Indicator) values are functions of one or more RTT reports' field values and/or other KPIs. In the simplest case they are counters. For counting the KPI values using the RTT reports, a KPI value may be simply increased by one, if a user definable condition is true for the analysed RTT report. The user definable condition is a comparison between some fields of RTT report data with predetermined values.

30

The KPI value can also be, in some of the embodiments, a function of at least one field values and/or other KPIs. For example, if the field value already counts something like the usage of a resource X like e.g. the amount of used time slots or seconds of used processor time, the KPI value can be a cumulative sum of field value in given time period. Furthermore, the field does not necessarily have to be a discrete count of something, it can be any kind of quantity measure.

10

Vectors are formed by using the KPI values as vector components such that the vector describes the functioning of the observable object, e.g. the NE, a part of a NE or a subscriber group. It is e.g. possible to attach each calculated KPI value as one component to the vector. In case one or some KPI values cause bad behavior in the sum model, such KPI values can be dropped from the vector. In principle there are no restrictions. One can select those KPIs that best describe the phenomenons one wants to monitor.

20

Vectors are formed because the used algorithm uses vectors as input data. The algorithm may be e.g. a self organising map (SOM) algorithm. A SOM algorithm is used in other network optimizing tasks as well and is a neural network algorithm.

25

Instead of a SOM based anomaly detection method, other methods may be used as well. These include, for example, K-means clustering, which resembles closely the used method, or other neural or statistical methods, e.g. coming from statistics in field of multivariate analysis, etc., provided that the methods are able to find anomalies (some times called also novelties) or sudden changes in multivariate time series.

30

There are several applicable distance measures for counting the distance between new incoming vectors and the best mapping node depending on the embodiment. The distance measure can be e.g. Kulback - Leibler distance for
5 histograms, or in some other embodiment the so called city block distance, or whatever norm is best suited for the embodiment.

The counting of a distribution for distances is preferably
10 done in discrete steps. All the incoming distances are recorded in a table or such, and it is counted how many distances occur at each discrete area. E.g. how many distances have been recorded between the range a...b, b...c, c...d, d...e, and how many recorded distances there are in
15 total. Then, the distribution can be calculated by dividing.

The distribution is a function that tells a probability for an incoming distance being less than a predetermined value directly. By giving an incoming distance as input to the
20 distribution, the output is how probable it is that a distance of given length occurs.

Fig. 1 shows the system architecture of a structure representing an embodiment of the invention. The embodiment
25 can be used in a communication system or network, e.g. of GPRS (General Packet Radio Service) or GSM structure such as a public land mobile network (PLMN). Mobile or fixed user terminals, e.g. GSM mobile station (MS) are able to receive services from, or communicate with other network elements.

30

Fig. 1 shows components of a first embodiment and their interaction. The components include one or more observable objects (OO), e.g. network elements (NE) 1. The NE 1 can be of any type that reports about its performance by some kind

of reports. A device or function 3, e.g. a storage, includes KPI definitions, i.e. definitions of generated KPIs that are created based on the information sent by Network Element 1. The KPI definitions can be common to all network elements of the same type, or can be specific for each element. The KPI definitions may be changeable on the fly, e.g. immediately when an operator changes the definitions, and can be given either as rules or formulas or in any other format that can be executed by a computer.

10

A KPI extractor 2 parses incoming messages from the NE 1 and eventually further NEs, and creates KPI vectors that describe the behavior of NE 1 or each NE. The KPI extractor 2 works on-line in real time, and delivers KPI vectors to a profile adapter 4 and anomaly detector 5 when defined in KPI definitions of means 3.

The profile adapter 4 creates and updates the behavior descriptor, i.e. NE profile, for each monitored NE 1 or each NE type. The update can be done in real time either after each generation or receipt of a KPI vector, or periodically after a given time interval or after a given number of received KPI vectors. The form of generated profile depends on the used anomaly detection method.

25

The anomaly detector 5 compares the most recent KPI vector of KPI extractor 2 to the behavior profile, i.e. NE profile received from profile adapter 4, and detects differences of the KPI vector in comparison to the NE profile. The detector 5 gets the profile of each NE or NE type from the profile adapter 4 either by request or periodically or whenever the adapter 4 is ready to submit such a profile. This can be implemented with one of several well-known anomaly detection methods.

30

The Anomaly detector 5 sends a report, i.e. Anomaly Information report, to a monitoring/reporting device 6 whenever it detects an interesting deviation in network element(s) behavior in comparison to the profile of the NE 1. This monitoring/reporting device can be either a dedicated monitoring application in a computer or an SMS- or HTTP-based application in a mobile device.

10 The components 2 to 6 can be implemented as processes in one or several separate computing devices or as specific circuits that are integrated with the network monitoring devices.

One example of the structure of an implementation architecture of the invention is shown in Figure 2. As shown in Fig. 2, a network element (NE) 10 sends RTT reports, e.g. as UDP (User Datagram Protocol) messages, to a network element TNES 11 which redirects such report messages to a network element TCAD 12. The TCAD 12 includes the means or functions 2, 4, 5 of Fig. 1, i.e. provides a KPI Extractor, Profile Adapter, and Anomaly Detector function/means. The TCAD 12 provides anomaly information reports and heartbeat reports and sends these reports to a network element TS 13. The TS 13 registers such reports and issues alarms in case of need.

The embodiments shown in Figs. 1, 2 provide a monitoring solution and contain means for collecting and storing real-time information from the network to detect faults in network elements and to monitor the quality of service provided by the network. This provides visibility to the network status in real-time at any time and anywhere.

Fig. 3 illustrates method steps of an embodiment of the

present invention. As shown by the arrow "Flow of RTT reports", the monitored network element sends RTT reports to a network component or another entity, e.g. CCMA. The CCMA (Clear Code Matrix) is a component of the Traffica product and it is responsible for calculating the KPI values from the RTT reports. It is a user-defined decision tree which consists of nodes and counters. Counters can be KPIs as such or KPIs can be calculated from two or more counters. There, in a step 1., user defined KPIs are updated e.g. at the counter tree, e.g. the CCMA according to the received RTT reports. With an appropriate timing, e.g. every 5th minute, a vector consisting of KPI values, will be output to the learning- and analyzing processes. As shown in Fig. 3, each output vector may be a sequence of KPI values, e.g. "(37, 15, 0, 3, 1)". This forming of a KPI vector for the or each monitored network element is depicted by step 2 of Fig. 3.

Each KPI vector is input to a learning process, step 3., as well as to an analyzing process, step 4. In the learning process, the received KPI vectors are used in counting periodically a profile for the monitored network element(s). The profile represents the functioning of the network element. When using the SOM algorithm, the profile is the trained SOM itself. The SOM consists then of k nodes (neurons). Each node is a vector of the same dimension as the KPI vectors. The number of nodes (k) ought to be dependent on the number of KPI vectors (n) in the training data. It could be e.g. desirable to have approximately $n = 20 * k$. When using SOM or K-means the profile consists of as many vectors as nodes or neurons and the distance distribution.

In the analyzing process, step 4., any new KPI vector received from step 2, will be compared to the profile formed in step 3 based on the previous KPI vectors, so as to detect

any surprising deviations therebetween which might indicate an alarm situation. Preferably, an anomaly P-value will be calculated for each new incoming vector. The value of P value can range e.g. between 0 and 100. The closer to 0 the value is, the more the new vector differs from the profile. In addition, the process will count which vector components will differ from the profile the most.

In the example shown in Fig. 3, the calculated P-value is 3,67. An anomaly threshold is set for comparison to the P-value which threshold may have the value of 5,0. In step 5., the P-value will be compared to the predetermined anomaly threshold. If the P-value is lower than the threshold, an anomaly indication will be generated, as indicated by the arrow shown in Fig. 3.

In step 6., an alarm will be generated, if the anomaly indication fulfils the conditions determined by the user.

The anomaly indication sent as a result of a positive comparison of step 5., includes information about the actual P-value leading to the alarm, and about which e.g. three components of the actual KPI vector differed the most from the profile. The mentioned number of three is just an example, the number of components reported to be differing the most from the profile can range from zero up to the number of components in the KPI vectors.

The invention can be implemented to support also other technologies than GSM. The adaptive monitoring and reporting can be implemented e.g. in a GPRS NE, e.g. a support node such as SGSN (Traffic for GPRS) or in CPS & MSS (Traffic for 3G and All-IP) network elements (CPS = Call Processing Subsystem; MSS = Management Statistic Subsystem). The

invention will support these adaptation layers as well.

The second embodiment of the invention described below and shown in Figs. 4 to 7 relates to anomaly detection in a computer or in telecommunication networks in which the concept of normal behaviour varies with time. The details of this embodiment as described below and shown in Figs. 4 to 7 can be arbitrarily combined with the details of the above discussed embodiments. More particularly, this embodiment relates especially to teaching an anomaly detection mechanism. An example of such an anomaly detection mechanism is based on self-organizing maps (SOM).

A problem with known SOM-based ADS mechanisms is that they are restricted to detecting problems in systems having a well-defined normal behaviour. In most telecommunication networks the concept of "normal behaviour" is, at best, vague. A network element's behaviour at peak time is very different from its behaviour at the quiet hours just before dawn. More precisely, most often it is the users' who cause the variation in what is called normal. In other words, known ADS mechanisms do not readily lend themselves to detecting problems in systems or elements whose normal behaviour varies with time.

Accordingly, this embodiment of the invention provides a mechanism for teaching ADS mechanisms which rely on the concept of normal behaviour in a system in which the normal behaviour varies significantly with time. In this context, "significantly" means that a behaviour which is normal at certain times is to be considered anomalous at other times.

This aspect of the invention is partially based on the idea that time is used as a component of the input data to the

ADS. But it is not sufficient to include time in the input data, if time is represented as a quantity which increases linearly from a fixed start point. This is because such a presentation of time is not repeating, and the ADS would not
5 know when a certain behaviour was normal and when anomalous. It is also not sufficient to introduce time as a periodic quantity (such as a 24-hour clock) because the daily jumps from 23:59 to 00:00 would introduce severe discontinuities to the input data.

10

Accordingly, the embodiment is also based on formulating a presentation of time which is suitable for solving the problem caused by the time-varying normal behaviour of systems such as telecommunication networks. According to this
15 aspect of the invention, the presentation of time which is used as a component of the input data is 1) periodic, 2) continuous and 3) unambiguous (within the period of the input data). A preferred example of such a presentation of time (t) is a projection to x and y components such that $x = \sin(2\pi t/L)$
20 and $y = \cos(2\pi t/L)$ where L is the length of the period of variation, typically 24 hours or a week. At first sight, such a two-dimensional presentation of time would seem to use both dimensions of a two-dimensional SOM map, but such SOM maps are for visualization purposes only, and inside a computer
25 memory, an SOM map can have an arbitrary number of dimensions.

The continuity requirement for the presentation of time should be interpreted with the constraints of reality in
30 mind, however. All digital systems have a finite resolution, which means that no presentation of time can be perfectly continuous. In addition, some memory can be saved when storing the observations by omitting some of the least significant bits of the observations, ie by quantization. For

- the purposes of the invention, a presentation of time is sufficiently continuous (= "large-scale continuous") if it does not contain discontinuities which are large enough to affect a decision between normal and anomalous behaviour. For example, in a telecommunication network with a usage period of 24 hours, discontinuities (quantizations) of up to about 10 or 15 minutes may be considered acceptable if there are no times at which user behaviour changes so fast that a certain type of behaviour is considered normal at a certain point of time but anomalous 10 or 15 minutes later. In contrast, the presentation of time for a system which opens and closes (or radically changes its behaviour in other ways) at well-defined times must have considerably smaller discontinuities.
- 15 Some memory can be saved if it is known beforehand that changes in the behaviour of the observable objects are small and/or gradual during certain parts of the period (such as nights) and more pronounced during other parts (such as days). In such a case, the presentation of time can be such that the resolution is variable within the period. This means that one bit may represent, say, 30 minutes during the quiet parts of the period and 5 - 15 during the more active parts of the period.
- 25 In some cases a single period (typically 24 hours) is sufficient, but sometimes two or three nested periods may be required. For example, the presentation of time may comprise one component with a 24-hour period and another with a one-week period. For locations or situations strongly affected by seasonal changes, a third component with a one-year period may be required.
- 30

This aspect of the invention is not limited to self-organizing maps but can be used with other clustering

techniques such as k-means or other corresponding neural or statistical algorithm.

According to a preferred embodiment of the invention, all
5 variables (components of the input data), including the presentation of time, are scaled such that the variance of each variable is the same, preferably one.

The invention can be implemented as software routines in a
10 computer system having access to the objects to be observed.

Fig. 4 shows a self-organizing map;

Fig. 5 is a variation of Fig. 4, with circles centred around
15 the neurons of the SOM;

Fig. 6 is a process chart illustrating the second embodiment;
and

20 Figs. 7A to 7C illustrate different presentations of time.

The following embodiments of the invention will be described in connection with self-organizing map (SOM) technology.

Figure 4 shows a self-organizing map. The objective with a
25 SOM test for anomaly is to test if the current behaviour of an observable object is anomalous or not. The hypothesis to be tested is:

H_0 : The most recent observation is not anomalous.

H_1 : The most recent observation is anomalous.

30

The behaviour of an observable object can be very consistent, which means that it is concentrated to one or a couple of regions in the feature space. On the other hand, the behaviour can also be more scattered in the feature space,

which would signify a more irregular behaviour. The idea of the SOM test for anomaly is to approximate the normal behaviour of an observable object with a small object-specific SOM. The previous behaviour is assumed to represent
 5 the normal behaviour of the observable object. Anomalous observations can be omitted from the previous behaviour when training the SOM.

The SOM shown in Fig. 4 is a one-dimensional (8*1) SOM with
 10 200 points of artificial data, commonly depicted by reference number 23. Fig. 5 shows the same SOM with circles or ellipses 31 plotted using the neurons 24 of the SOM as centres. For clarity, Figs. 4 and 5 are shown with only two features 21 and 22, but in reality, the number of observable features can
 15 be much larger than two.

200 points of artificial data for two features have been plotted in the plane together with the neurons of a map of size 8*1 trained with the data. The one-dimensional SOM
 20 approximates two clusters (having four ellipses 31 each) of data quite well. Note that the data in Fig. 4 is two-dimensional to allow visualization to humans. In a computer system, the number of dimensions can be much larger than two. The Best Mapping Unit (BMU) for a data point f_k in an SOM is
 25 the neuron w_i having the smallest distance to the data point. This is expressed in equation (1), where dist stands for the distance.

$$BMU = \underset{i}{\operatorname{argmin}} \{ \text{dist}(f_k, w_i) \} \quad (1)$$

Here, we assume that a Euclidean distance to the BMU is used
 30 to measure how much an observation deviates from the normal object-specific behaviour, but other types of distance measurements can be used. The anomaly P-value is a measure of the degree of anomaly for an observation. On the basis of

this value, the hypothesis H_0 is accepted or rejected. Calculation of the anomaly P-value will be described in connection with the use phase of the SOM-based ADS.

- 5 An ADS mechanism involves three major phases, design, teaching and use. The design phase typically involves some decisions and comprises the following steps:

1. Selecting a set of features describing the target object.
- 10 The feature vector describing the object is denoted by f . (The target object is the object to be observed, such as a network element.) This step is described in detail in the above referenced article. For the purposes of the present aspect of the invention, it suffices to say that the features
15 are parameters which can be used to make a distinction between normal and anomalous behaviour.

2. Formulating a hypothesis for detecting anomalous behaviour. The objective is to test the most recent
20 observation f_{n+1} for anomaly. The hypothesis to be tested is H_0 : The most recent observation f_{n+1} is not anomalous. The alternative hypothesis is H_1 : The most recent observation f_{n+1} is anomalous. (The suffix n will be described in connection with the use phase.)

- 25 The teaching (learning) phase typically comprises the following steps:

1. Observing normal behaviour of the target object. For example, n measurements (f_1, f_2, \dots, f_n) of the feature
30 vector are collected.
2. Training an SOM with m neurons using the measurements (f_1, f_2, \dots, f_n) as training data. The number of neurons in the map, m , is selected to be much smaller than n , for

example $n/10$.

The use phase typically comprises the following steps:

1. Omitting neurons in the SOM that are not Best Mapping Units (BMU) for any of the data points (f_1, f_2, \dots, f_n) .
- 5 2. Calculating the BMU distances for (f_1, f_2, \dots, f_n) from the trained SOM. These distances are denoted by (D_1, D_2, \dots, D_n) .
3. Calculating the BMU distance for the observation f_{n+1} . This distance is denoted by D_{n+1} .
- 10 4. Calculating the anomaly P-value. Let B be the number of the Best Mapping Unit distances (D_1, D_2, \dots, D_n) higher than D_{n+1} . The anomaly P-value for a certain object is then calculated from:

$$P_{n+1} = \frac{B}{n} \quad (2)$$

- 15 5. Accepting or rejecting the null hypothesis on the basis of the anomaly P-value. If the anomaly P-value is higher than the anomaly P-value threshold, the null hypothesis H_0 is accepted (the most recent observation is considered normal). If, on the other hand, the anomaly P-value is smaller than
- 20 the anomaly P-value threshold, the null hypothesis H_0 is rejected and the most recent data point is assumed anomalous.

If the test indicates that the object behaviour is anomalous (H_0 is rejected), the k most significantly deviating features can be determined. The k features (components of the feature

25 vector) with the biggest absolute contribution to the BMU distance are the k most significantly deviating features. Equation (3) shows how the most deviating feature can be calculated. This component of the feature vector is given the sub-index md in equation (3). In equation (3) BMU stands for

30 the Best Mapping Unit of the feature vector f_{n+1} , and j takes values from zero to the number of features. The other $k-1$ most deviating features are calculated in a corresponding

manner.

$$f_{n+1,md} = \arg \max_j \{ \text{abs}(f_{n+1,j} - \text{BMU}_j) \} \quad (3)$$

The situation shown in Fig. 4 can be used as an example. Fig. 4 shows two anomalies, commonly depicted with reference numeral 25. The anomaly P-value for anomaly 1 is $0/200 = 0$. Since none of the BMU distances for the data points have a BMU distance greater than that of anomaly 1, the value of the numerator is zero. Correspondingly, the anomaly P-value for anomaly 2 is $7/200 = 0.035$.

10

If the Anomaly P-value is smaller than the Anomaly P-value threshold, the null hypothesis H_0 is rejected and an alarm is triggered. The Anomaly P-value threshold can be interpreted as the fraction of observations that will be rejected if the behaviour of the observable object does not deviate from the the same observable object's earlier behaviour which was used during the teaching phase. That is, if the null hypothesis is true:

$$\text{number of alarms} = \text{P-value threshold} * \text{observations} \quad (4)$$

20 On the other hand, if the null hypothesis is not true (the new data is anomalous), the number of rejections (alarms) is higher.

Fig. 5 shows how a selected P-value threshold can be illustrated for observable object i using d -dimensional spheres (d -spheres) centred at the neurons of the object-specific map. With two-dimensional input data, the d -spheres are circles. Here d stands for the number of dimensions in the input data (f_1, f_2, \dots, f_n) . In other words, each input data element f_1 through f_n is itself a vector with d dimensions. The number of observations for object i falling outside the spheres corresponds to the numerator B in equation (2). The two-dimensional example in Fig. 5 shows

30

such a situation. Here B is 13, which corresponds to quite high a P-value threshold of about 6.50.

Fig. 6 is a process chart illustrating a the second embodiment of the invention. Reference number 302 points to an element of a physical system such as a telecommunication network (as distinguished from a neural network). A physical element may comprise several observable objects. For example, if the physical system element 302 is a telecommunication exchange, its observable objects may comprise throughput, waiting time, number (or percentage) of failed calls and the like. For each unit of time, an indicator collector 306 collects an indicator tuple 304. The tuples are stored in an indicator database 310. Reference 312 points to a data set used for training the neural network (or another learning mechanism) 314. The data set 312 should indicate normal behaviour of the physical element 302. A storage 318 contains trained neural networks. When a physical element 302 is to be observed, the corresponding trained neural network 320 is retrieved from the storage 318 and applied as one input to the anomaly detection mechanism 322. The anomaly detection mechanism's other input is the indicator set 324 to be tested for anomalous behaviour. If the anomaly detection mechanism 322 decides that the behaviour described by the indicator set 324 is anomalous, the anomaly P-value and the most deviating indicators 326 are stored in an anomaly history database 328. At the same time, an alarm 330 is given to a monitoring device 332, such as a computer screen.

Figs. 7A to 7C illustrate different presentations of time, some of which are acceptable and some unacceptable. In Fig. 7A, the horizontal axis is the time in units of L where L is the period of input data, which is assumed to be 24 hours. Line 400 shows a straight presentation of time. References 401 to 403 point to three instances of a repeating event

which occurs at 24-hour intervals. A problem with this presentation of time is that the presentations of the times are different, and the ADS cannot recognize events 401 to 403 as a recurring event.

- 5 The saw-tooth line 405 is a 24-hour presentation of time, or in other words, a modulo function of time. In this presentation, events occurring at the same time each day have identical representations, but the day changes introduce discontinuities into the input data.
- 10 In Fig. 7B, the sine wave 410 is periodic and continuous, but it is not ambiguous. Events 411 and 412 occur at different times but have identical presentations of time. Assuming that event 411 was normal in the morning, the ADS would not recognize a similar event as an anomaly if it occurred in the
- 15 evening.

Fig. 7C shows three acceptable presentations of time. They are all based on the idea that time is represented as a coordinate pair x, y . The circle 420 represents time as

20 $\{x=\sin(2\pi t/L); y=\cos(2\pi t/L)\}$ where L is the length of the variation period, and $2\pi t/L$ is an angle from the x axis. The ellipse 422 is also acceptable as long as it is not too flat to introduce an ambiguity as to whether a point is on the top half or the bottom half of the ellipse. Even a rectangle 424

25 can be used. Although several points have identical x or y coordinates, no two points of the rectangle have identical x/y coordinate pairs.

The sine/cosine combination of the circle 420 is considered a

30 preferred presentation of time because events which are equidistant in time are also equidistant in the presentation of time. However, the sine/cosine combination may be computationally intensive, and some approximations, such as a pair of triangular wave functions with a 90-degree phase

shift, can be used.

As stated earlier, in some situations the presentation of time may require more than one component. For example, there
5 may be up to three sine/cosine pairs with periods of 24 hours, one week and one year.

Although preferred embodiments of the invention have been described in connection with neural networks and self-
10 organizing maps, the invention is not limited to these examples. As an alternative, the invention can be generalized to other clustering techniques such as k-means and Learning Vector Quantization, in which case the neurons are replaced by codebook vectors.

15 This embodiment provides a method for teaching an anomaly detecting mechanism in a system comprising observable objects (302), at least one of which has a periodic time-dependent behaviour, the anomaly detecting mechanism comprising a
20 computerized learning mechanism (314) having an input space for defining input data consisting of input data components (11, 12);

the method comprising:
assembling indicators (304) indicating the behaviour of the
25 observable objects (302) and arranging the assembled indicators such that each observable object's indicators are assigned to the same input data component;
teaching the learning mechanism (314) such that the input data of the learning mechanism comprises the input data
30 components which are based on the assembled indicators (304);
placing points (14) which approximate the input data in the input space;
incorporating a presentation of time (420 - 424) into at least one input data component (11, 12);

wherein the presentation of time (420 - 424) is periodic, continuous and unambiguous within the period (L) of the at least one element with periodic time-dependent behaviour.

- 5 In this method, the learning mechanism may be or comprise a self-organizing map.

The presentation of time may have a first period and at least one second period which is a multiple of the first period.

10

The input data components may be scaled such that each has the same variance, preferably one.

- 15 The presentation of time preferably has a variable resolution such that one bit corresponds to different units of time depending on the changes in the time-dependent behaviour.

- This aspect of the invention furthermore provides an arrangement for detecting anomalies in a system comprising observable objects, at least one of which has a periodic time-dependent behaviour;
- 20 the arrangement comprising:
- a computerized learning mechanism having an input space for defining input data consisting of input data components;
- 25 means for assembling indicators indicating the behaviour of the observable objects and arranging the assembled indicators such that each observable object's indicators are assigned to the same input data component;
- means for teaching the learning mechanism such that the input
- 30 data of the learning mechanism comprises the input data components which are based on the assembled indicators;
- means for placing points which approximate the input data in the input space;
- at least one input data component comprising a presentation

of time;

wherein the presentation of time is periodic, continuous and unambiguous within the period of the at least one element with periodic time-dependent behaviour.

5

The arrangement may be comprised in a single network element.

According to one aspect of the invention, a computer readable storage medium is provided which comprises software for a
10 computer, wherein executing the software in the computer causes the computer to carry out all or part of the above mentioned method steps.

The above described method and apparatus are adapted for
15 teaching an anomaly detecting mechanism in a system comprising observable objects, at least one of which has a periodic time-dependent behaviour. The anomaly detecting mechanism comprises a computerized learning mechanism. The method comprises assembling indicators indicating the
20 behaviour of the elements and arranging the assembled indicators such that each observable object's indicators are assigned to the same input data component. The learning mechanism is taught so that the input data of the learning mechanism comprises the input data components which are based
25 on the assembled indicators. Points which approximate the input data are placed in the input space. A presentation of time is incorporated into at least one input data component wherein the presentation of time is periodic, continuous and unambiguous within the period of the at least one element
30 with periodic time-dependent behaviour.

The invention can also be used in other industry areas than telecommunications and networks.

Although the invention has been described above with reference to specific embodiments, the scope of the invention also covers any alterations, additions, modifications, and omissions of the disclosed features.

CLAIMS

5

1. Method for monitoring the behaviour of at least one observable object of a network, wherein at least one parameter of the observable object is repeatedly detected,

10

the at least one parameter is checked with regard to fulfilling predetermined criteria,

a vector is formed based on the monitored parameter depending on the result of the checking step,

and the formed vector is evaluated for monitoring the behaviour of the observable object.

15

2. Method according to claim 1, wherein the formed vector is input to a learning process and to an analyzing process,

20

the learning process is forming a reference, based on the input vector and a previous value of the reference or at least one previously input vector, for describing the behaviour of the observable object, and

the analyzing process is comparing the input vector and the reference for detecting anomalous behaviour.

25

3. Method according to claim 1 or 2, wherein the number of parameters that fulfil the predetermined criteria during an observation period, is counted, for forming KPI values which form part of the vector, each parameter having its own criteria.

30

4. Method according to claim 3, wherein, when an RTT report value fulfils the predetermined criteria, value of one

KPI is increased by one.

5 5. Method according to claim 3, wherein KPI value is a function of at least one predetermined RTT report field values of such RTT reports that fulfil the predetermined criteria.

6. Method according to claim 3, wherein KPI value is a function of at least one other KPI.

10

7. Method according to any one of claims 1 to 6, wherein the predetermined criteria are checked by comparing fields of an RTT report to predetermined field thresholds.

15 8. Method according to claim 4, 5, 6 or 7, wherein an RTT report containing the parameter values includes fields defining the

-end cause code,

-a length of call,

20 -sender identification,

-receiver identification,

-location information,

-used network resources,

and/or

25 -used services.

9. Method according to claim 3, wherein the predetermined criteria and the observation period are user definable.

30

10. Method according to any one of the preceding claims, wherein the vector comprises several values which describe properties or functioning of the observable object.

11. Method according to any one of the preceding claims, wherein the vector is formed based on detected values in RTT (Real Time Traffic) reports.

5 12. Method according to claim 2, wherein the reference formed by the learning process is a profile generated from at least two vectors.

10 13. Method according to any one of claims 2 to 12, wherein the learning process comprises a self organizing map (SOM).

15 14. Method according to any one of claims 2 to 12, wherein the learning process comprises a K-means algorithm.

15 15. Method according to any one of claims 2 to 14, comprising the steps:

- Using the vector as input data to an algorithm which learns the normal functioning of the network, and forms the reference as a profile describing the normal functioning of the network, the profile consisting of nodes or cluster centroids,
- Finding best mapping nodes or cluster centroids of the profile for a new incoming vector;
- 25 - Counting distance between the new incoming vector and the best mapping nodes or cluster centroids;
- Counting a distribution of distances;
- Checking from the distribution whether a distance of the new incoming vector represents a probability which is
- 30 less than a predetermined probability set-up value;
- Generating an alarm, if the check result is positive.


16. System for monitoring the behaviour of at least one observable object of a network, comprising a detecting means

for detecting at least one parameter of the observable object, means for checking the at least one parameter with regard to fulfilling predetermined criteria, means for forming a vector based on the monitored parameter depending on the result of the checking step, and means for evaluating the formed vector for monitoring the behaviour of the observable object.

17. System according to claim 16, comprising
10 a learning means for receiving an actually calculated vector and forming a reference, based on at least two vectors, for describing the behaviour of the observable object, and an analyzing means for receiving the actually calculated vector and comparing the received vector and the reference for
15 detecting anomalous behaviour.

18. System according to any one of the preceding system claims, wherein the parameter is formed based on detected RTT (Real Time Traffic) report field values.
20

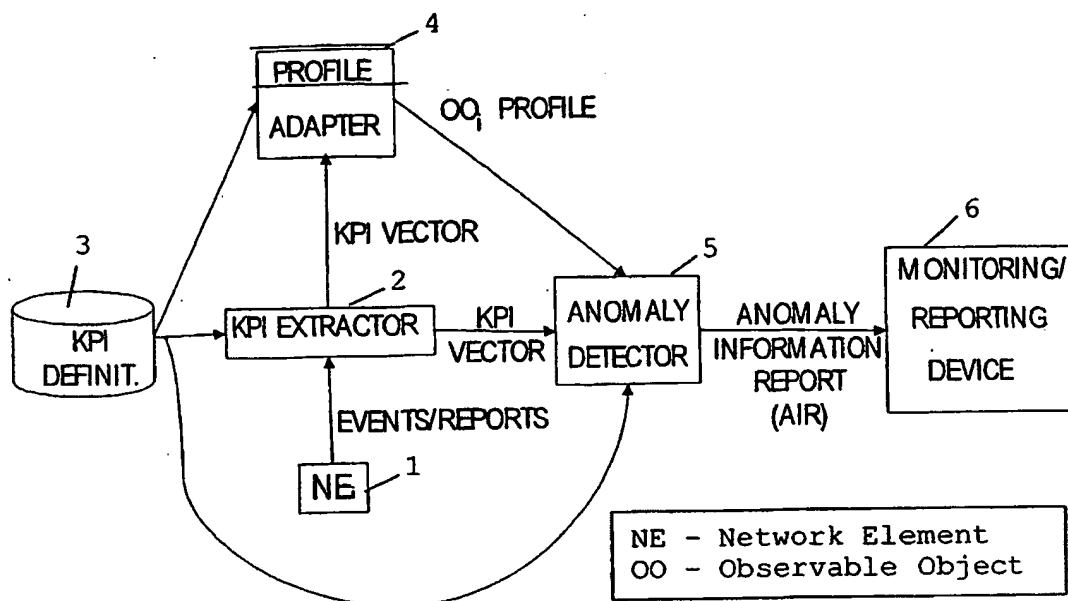
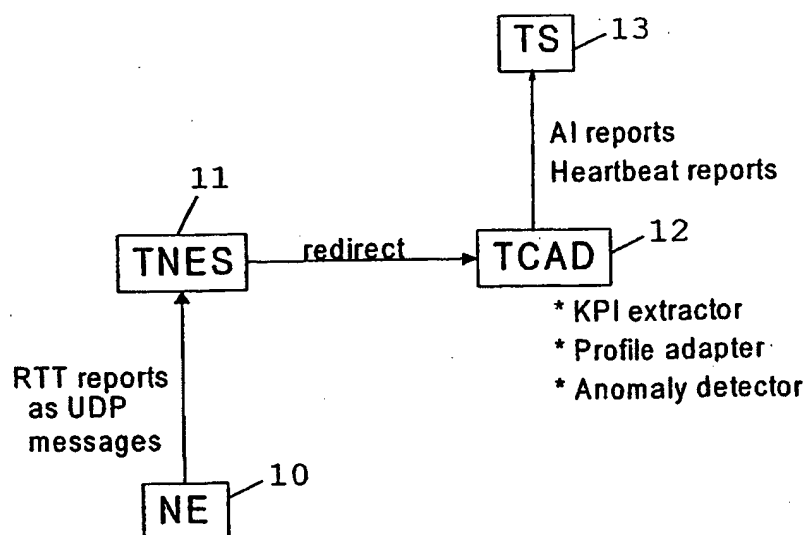
19. System according to any one of the preceding system claims, comprising means for:

- 25  - Using the vector as input data to an algorithm which learns the normal functioning of the network, and forms, as a reference, a profile describing the normal functioning of the network, the profile consisting of nodes or cluster centroids;
- Finding best mapping nodes or cluster centroids of the profile for a new incoming vector;
- 30 - Counting distance between the new incoming vector and the best mapping nodes or cluster centroids;
- Counting a distribution of distances;
- Checking whether a distance of an incoming vector has a probability value less than a predetermined probability

set-up value; and

- Generating an alarm, if the check result is positive.

20. System according to claim 17, wherein the learning
5 means includes a self organizing map (SOM) or K-means
algorithm.

**FIG. 1****FIG. 2**

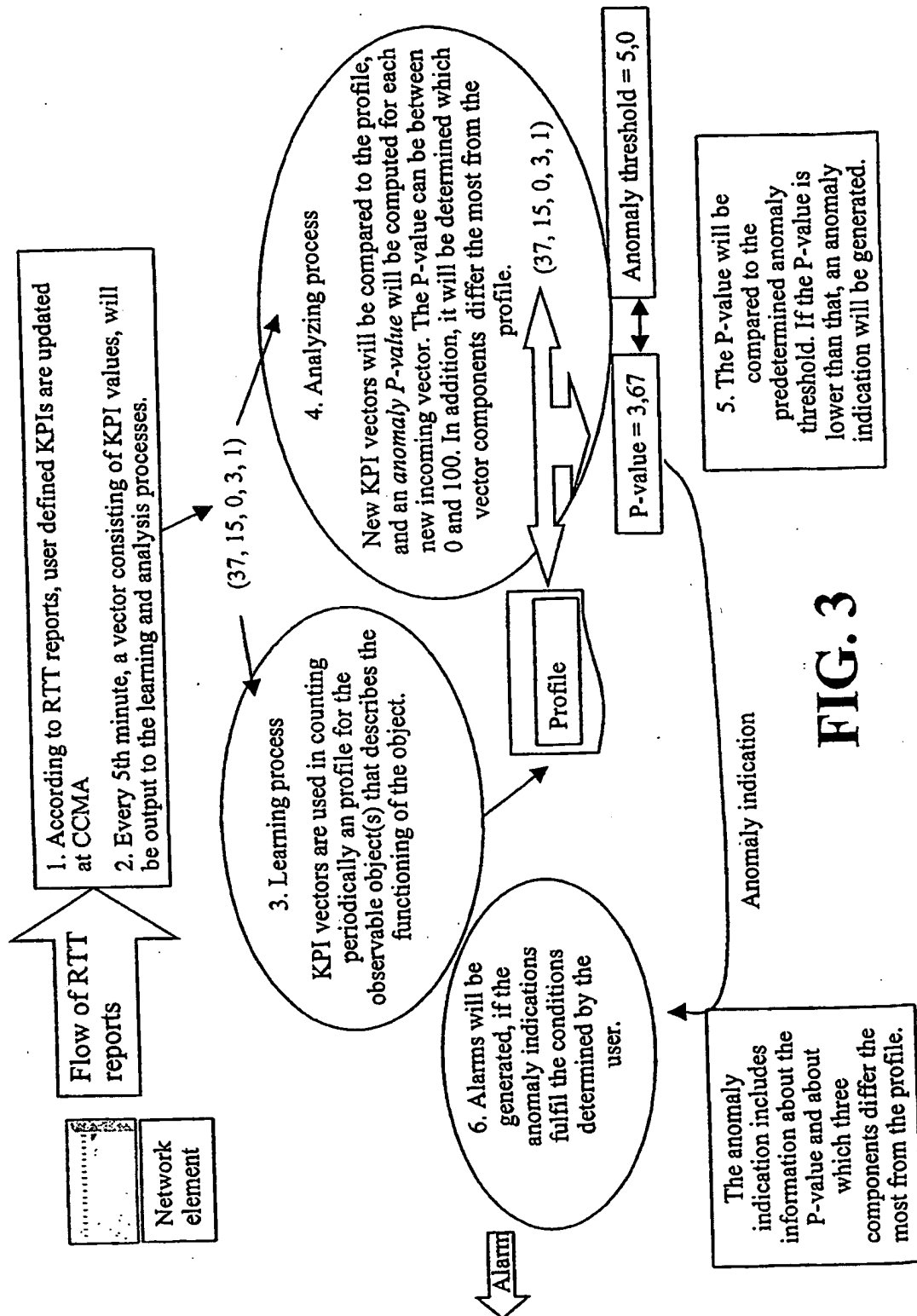


FIG. 4

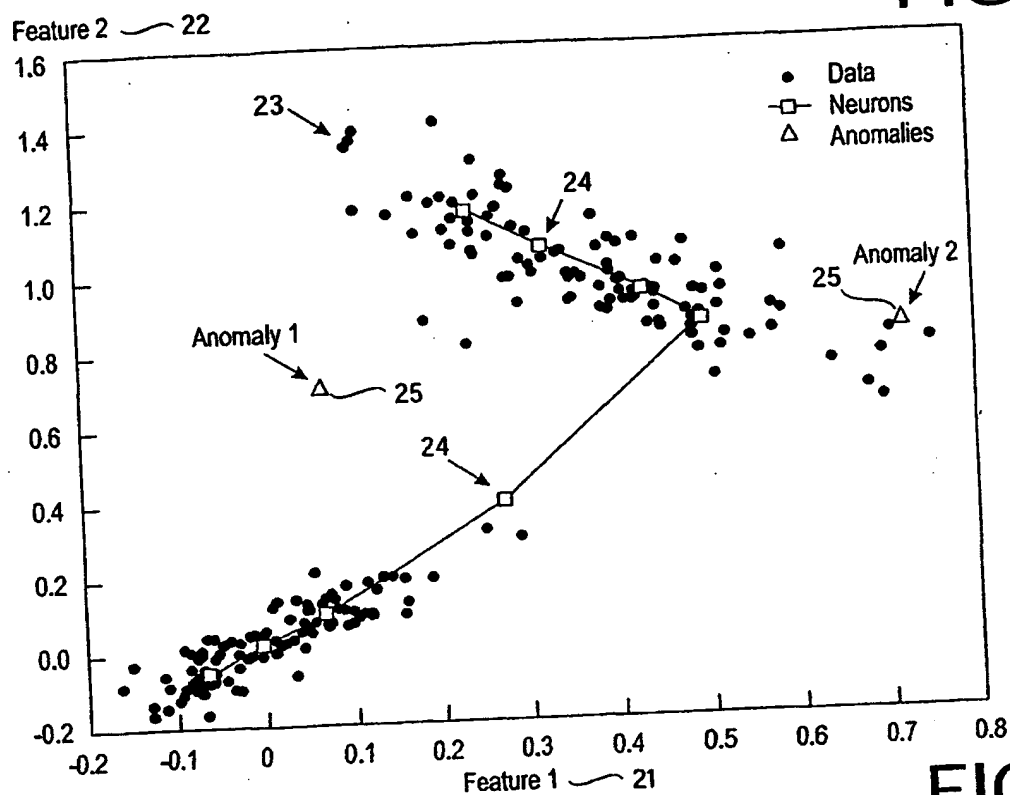


FIG. 5

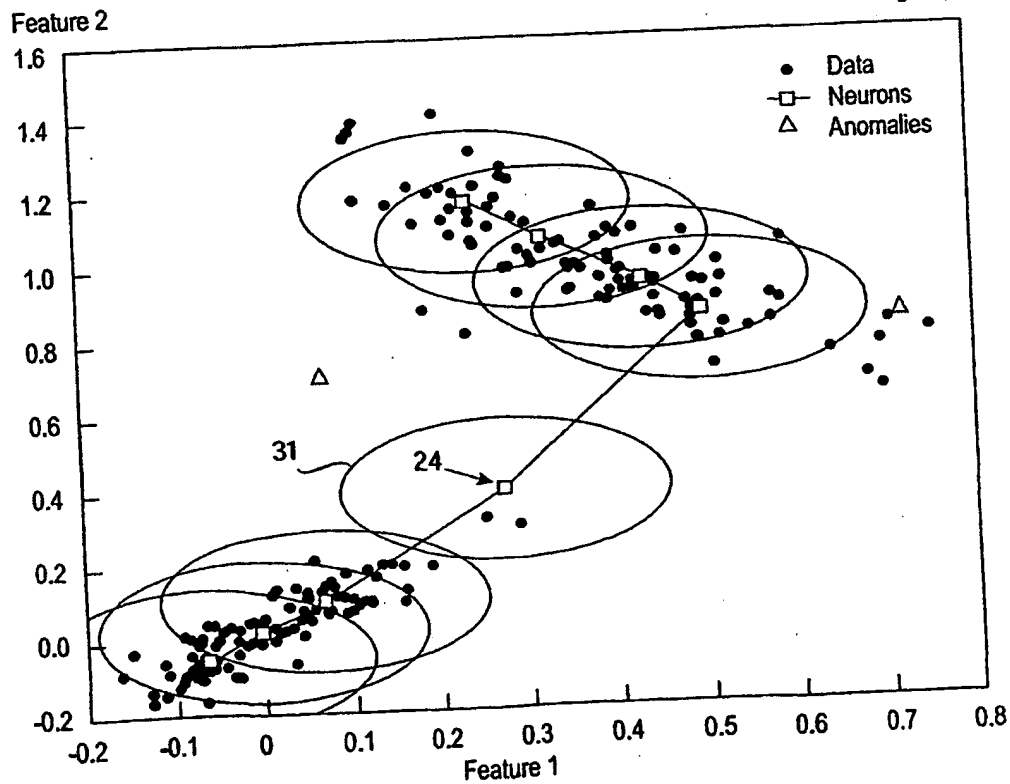


FIG. 6

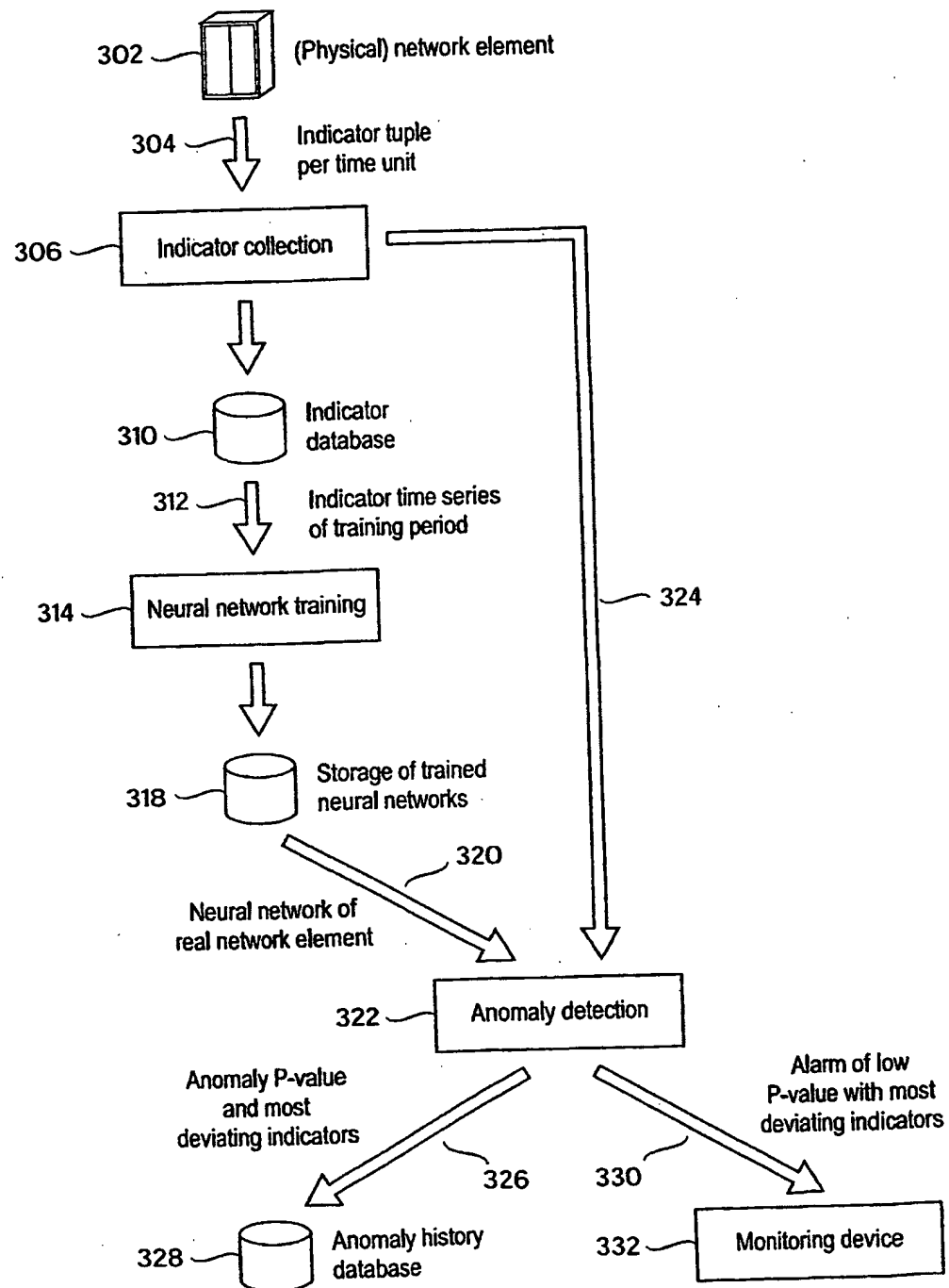


FIG. 7A

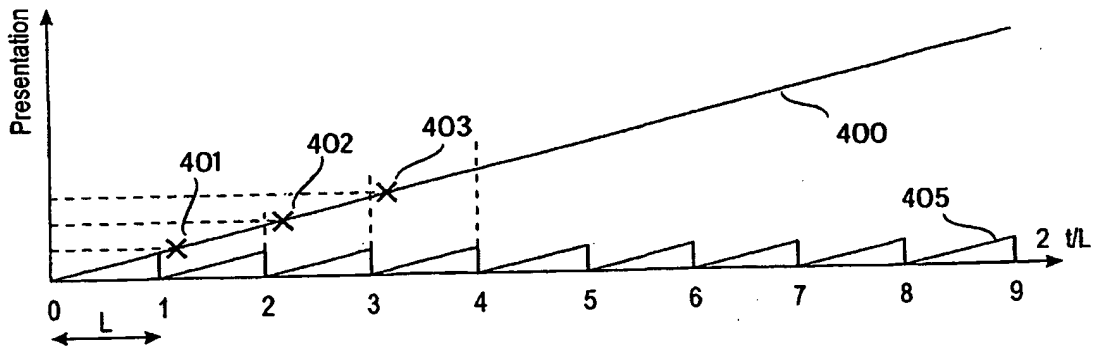


FIG. 7B

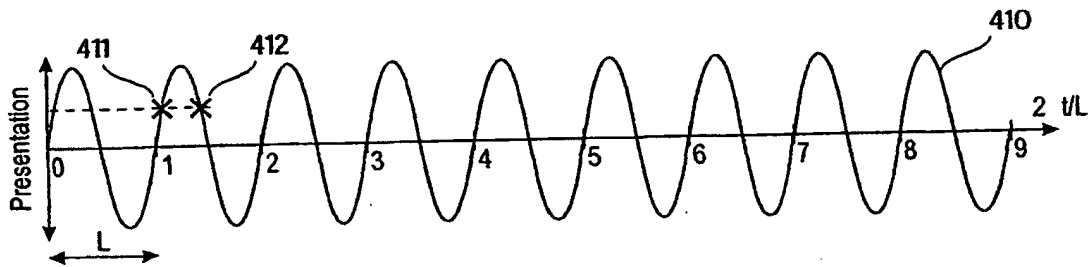
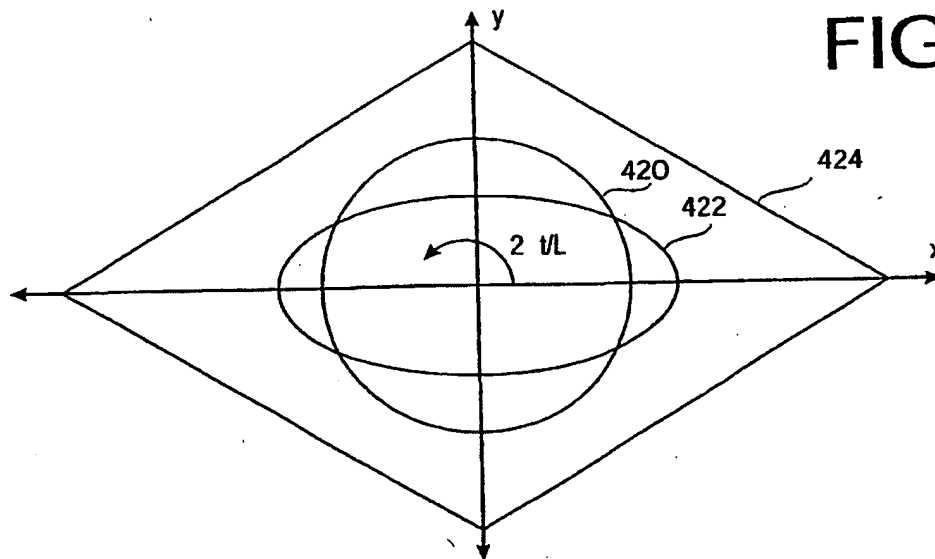


FIG. 7C



INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 01/06405

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L12/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L H04M G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	HOGLUND A J ET AL: "A computer host-based user anomaly detection system using the self-organizing map" PROCEEDINGS IEEE INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS 2000 IJCNN2000, vol. 5, 24 - 27 July 2000, pages 411-416, XP002901865 Finland the whole document	1-5, 7-11, 13-16, 18-20
Y	---	13-15, 19,20
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 01/06405

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 661 847 A (IBM) 5 July 1995 (1995-07-05) page 5, line 12 -page 10, line 52 abstract; claims 1-9; figures 1-6A	1-12, 16-18
Y	---	13-15, 19,20
X	US 5 987 442 A (LEWIS L ET AL) 16 November 1999 (1999-11-16) column 1, line 10 -column 2, line 19 column 3, line 20 -column 5, line 25 abstract; claims 6-10; figure 1	1-4, 6-11,13, 16,18,20
X	---	
X	US 5 317 725 A (SMITH M S ET AL) 31 May 1994 (1994-05-31) column 1, line 15 -column 3, line 40 column 5, line 5 -column 11, line 18 column 33, line 28 -column 34, line 46 abstract	1,2,7, 10,16-18
Y		13-15, 19,20
X	---	
X	EP 0 849 910 A (NORTHERN TELECOM LTD) 24 June 1998 (1998-06-24) column 6, line 15 -column 7, line 8 abstract	1,16

INTERNATIONAL SEARCH REPORT

In International Application No

PCT/EP 01/06405

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0661847	A	05-07-1995	US 5446874 A CA 2137491 A1 EP 0661847 A2	29-08-1995 24-06-1995 05-07-1995
US 5987442	A	16-11-1999	AT 191112 T AU 692369 B2 AU 4905796 A DE 69607324 D1 DE 69607324 T2 EP 0807348 A2 WO 9624210 A2	15-04-2000 04-06-1998 21-08-1996 27-04-2000 24-08-2000 19-11-1997 08-08-1996
US 5317725	A	31-05-1994	DE 69225518 D1 DE 69225518 T2 EP 0503921 A2 JP 5083257 A	25-06-1998 10-09-1998 16-09-1992 02-04-1993
EP 0849910	A	24-06-1998	CA 2221527 A1 EP 0849910 A2 JP 10190661 A	18-06-1998 24-06-1998 21-07-1998